CSmith

ENGINEERING CASE LIBRARY

ECL 108A

THREE PROBLEMS AT APEX ELECTRONICS

A. The Radio Interference Problem

The Company

Apex Electronics Limited was a firm which designed and manufactured electronic equipment for the consumer market and for the military market. Annual sales of television and Hi-Fi sets to the consumer market were about $3,000,000. Their military sales were about double this. Total employment was about 400 persons.

Apex was located in a city with a population of about 250,000 persons. The company had been there for more than thirty years. Many of its employees had worked for all of the thirty years.

 Prepared by Sidney F. Love with support from the National Science Foundation through the Engineering Case Program, Design Division, Department of Mechanical Engineering.

The Products

The television and Hi-Fi products were of average quality and priced in the medium price range. Competition with other manufacturers serving the same market was severe. Apex survived in this environment by a sales policy of giving exclusive dealerships to appliance dealers in small towns. A dealer could then sell the products on their performance merits without getting into a price-cutting competition with another dealer in the same district. The dealer made enough profit to properly service the products in warranty and thus built up a customer loyalty. In turn, Apex backed the dealer with good products and good warranty policies. They in turn got the dealer's loyalty to the Apex brand of products. Apex took special care never to give the dealer poor-looking merchandise. Any customer complaints were taken very seriously.

The Facilities

Like most electronic manufacturers, Apex purchased all of the electronic components such as resistors, condensers, speakers, knobs and wooden cabinets. They made most of their metal parts. There was a large sheet metal shop for cutting, punching, forming, plating and painting the metal parts. They, therefore, made their own metal chassis bases for TV and Hi-Fi. For portable TV sets, they also made the metal cabinets.

The Engineering Department

Their Engineering Department was small because of their limited annual sales. There were three engineers and three technicians who were responsible for the TV and Hi-Fi design. They were backed by a mechanical engineer and two draftsmen. A consulting engineer came once a week to help them with the design of their new color TV set.

The Personnel In The Case Study

Ralph Smith, the consulting engineer, was about forty-five years old. He was a university graduate and had practiced as an electronics engineer for about twenty years. He had been involved in many television designs, including color television which was new to Apex.

Peter Brutowski, at thirty-nine, was a self-made man. He had finished high school but had not gone on to college. In the Air Force, he had been trained as an electronics technician. After his military service, he worked for a while as a television serviceman in the Apex factory. Because he was found to be better than the average technician, he was picked to help the chief engineer in the laboratory. A few years later, the chief engineer had died suddenly and Peter had taken over the designing position. Since then, he had designed several successful black-and-white television sets and some Hi-Fi sets. He was now recognized as an engineer by Apex because of his ability to do the work.

*The Problem**

The president of Apex Electronics had a new Apex color TV set (Exhibit A-1) installed in his home. He noticed severe interference on a radio set when the color TV was turned on. It did not occur when the black-and-white TV was turned on. He had not noticed this interference with other color TV sets that he had used in his home.

The chief television engineer, Allan Miller, was asked to look into the problem. That same day be observed that the same effect could be duplicated in the laboratory. The color TV caused an interfering buzz on radios in the laboratory, even on strong local radio stations. He tried out a newer design of color TV and found that it did not cause this peculiar type of radio interference.

The problem was then handed over to their consulting engineer, Ralph Smith. He was asked to measure the interference level of the TV by a technique which was an industry standard. When the problem was demonstrated to him, he was puzzled by the peculiar type of radio interference, which he had never noticed before in his wide experience. He tried out various radios, various TV's, various antennae and various power connections. He tentatively concluded that the radiation to the nearby radios was conducted to them through the power an antenna wires. Both Ralph and Allan assumed that the source of the radio interference was the harmonics of the base frequency of 15,750 cycles per second extended into the radio band and required suppression.

The consulting engineer and an assistant, Peter Brutowski, took the color TV to a special electrostatically shielded room and proceeded to measure the radio interference. They found that at some frequencies the interference was over the government limit. However, they also noticed that it caused similar interference even at frequencies outside of the range of household radios. Puzzled by the outcome, the engineer used an oscilloscope to examine the nature of the buzz caused by the interference. He found that it had a 120 cycles per second (cps) frequency. A normal TV would cause a 60 cps buzz if the radio was very close to it.

Ralph and Peter then wrote down some hypotheses and tests in order to find the basic cause of the radio interference.

Hypothesis	*Test*	*Result*
–Bad joint on a power rectifier? (Peter)	–Look at it; bang it; pull out the vertical sweep tube	–No change in the buzz on the radio buzz on the
–Caused by high voltage regulator tube? (Ralph)	–Pull out the regulator tube	–No change in buzz

–Video amplifier being overdriven by too much video signal on its grind? (Ralph)	–Vary AGC control so video signal will be changed	–Less buzz when video signal reduced by AGC control, but not quite the same as when video signal reduced by the contrast control
–120 cps in Horizontal AFC because FM detection gives more output than AM (Ralph)	–Look at vertical lines in picture for double bend over one vertical scan	–No double bend in the vertical line in the TV picture
–Caused by tubes in color circuits (Peter)	–Color tubes removed	–No change in buzz
–One rectifier is open circuited (Peter)	–Would give 60 cps hum	–Buzz is 120 cps
–Insufficient filtering in power supply (Ralph)	–Add large capacitor to all filters	–No change in buzz
–Caused by picture tube (Peter)	–Remove picture tube socket and turn set on again	–No change in buzz

At this point Rod Bingham, a semi-technical person, interrupted.

"What are you guys doing anyway? You've got so much equipment set up you can hardly move around."

Since they were not getting anywhere with the problem anyway, Ralph took time off to explain it. He had to simplify his terms and explanations so that the other person could understand what it was about.

Ralph: "The boss discovered a new problem for us. This TV set kicks up hell on his radio set. Here, listen."

Rod: "Sounds funny to me, but nothing like the submarine detectors I used to operate in the Navy. It's like hum, isn't it?"

Peter: "Yes, but it's not the same as we get when a rectifier is shot."

Ralph: "Right. It's not 60 cycles, but 120 cycles. Look at the jagged waveform on this 'scope here."

As a result of explaining the problem, Ralph once again was brought to consider the relationship between 120 cps and a single rectifier (see first hypothesis). This was related to some past experience on rectifier radiation. The flash of insight resulted in a new hypothesis.

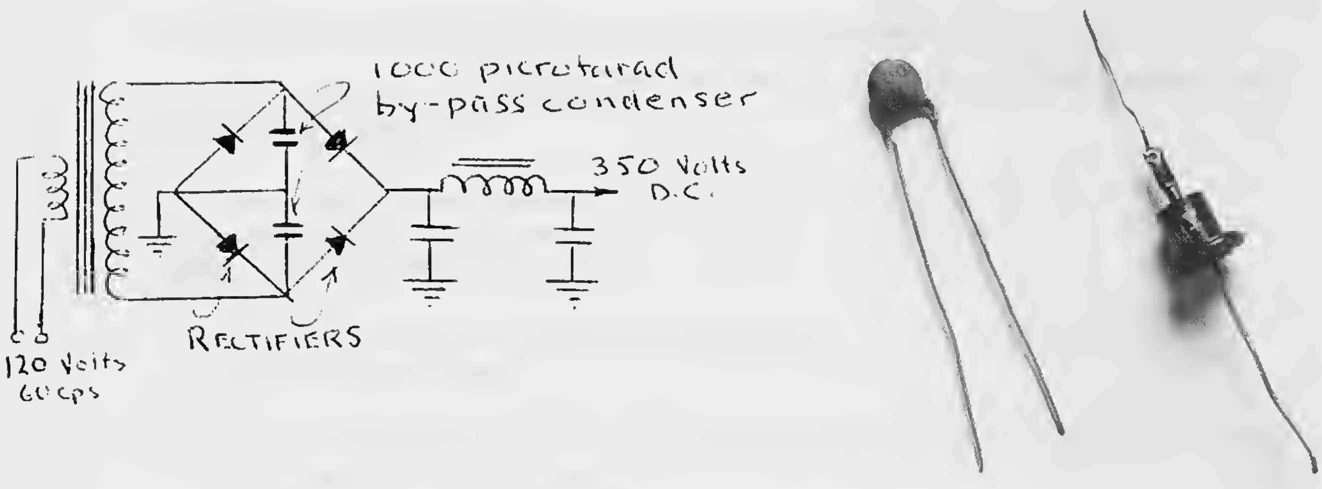
Hypothesis	*Test*	*Result*
–120 cps buzz caused by same phenomenon which causes rectifier radiation (Ralph)	–Put capacitors from rectifier to ground	–A 5000 picro-farad capacitor will stop the radiation
–Present capacitors inadequate (Ralph)	–Remove and substitute various values	–A capacitor with a minimum of 5000 picrofarads is needed and circuit has only 1000 picrofarads (Exhibit A-2)
–Rectifiers at fault (Peter)	–Replace with some of different make	–Not done because none were at hand

Exhibit A-2 is a simplification of the rectifier circuit. Exhibit A-3 is from a detailed schematic of the color TV circuit for those who are able to understand one of the type used by Ralph and Peter.

It was tentatively concluded that the rectifier radiation was the *key obstacle* in the way of *accomplishing* a TV which did not cause buzz on a radio.

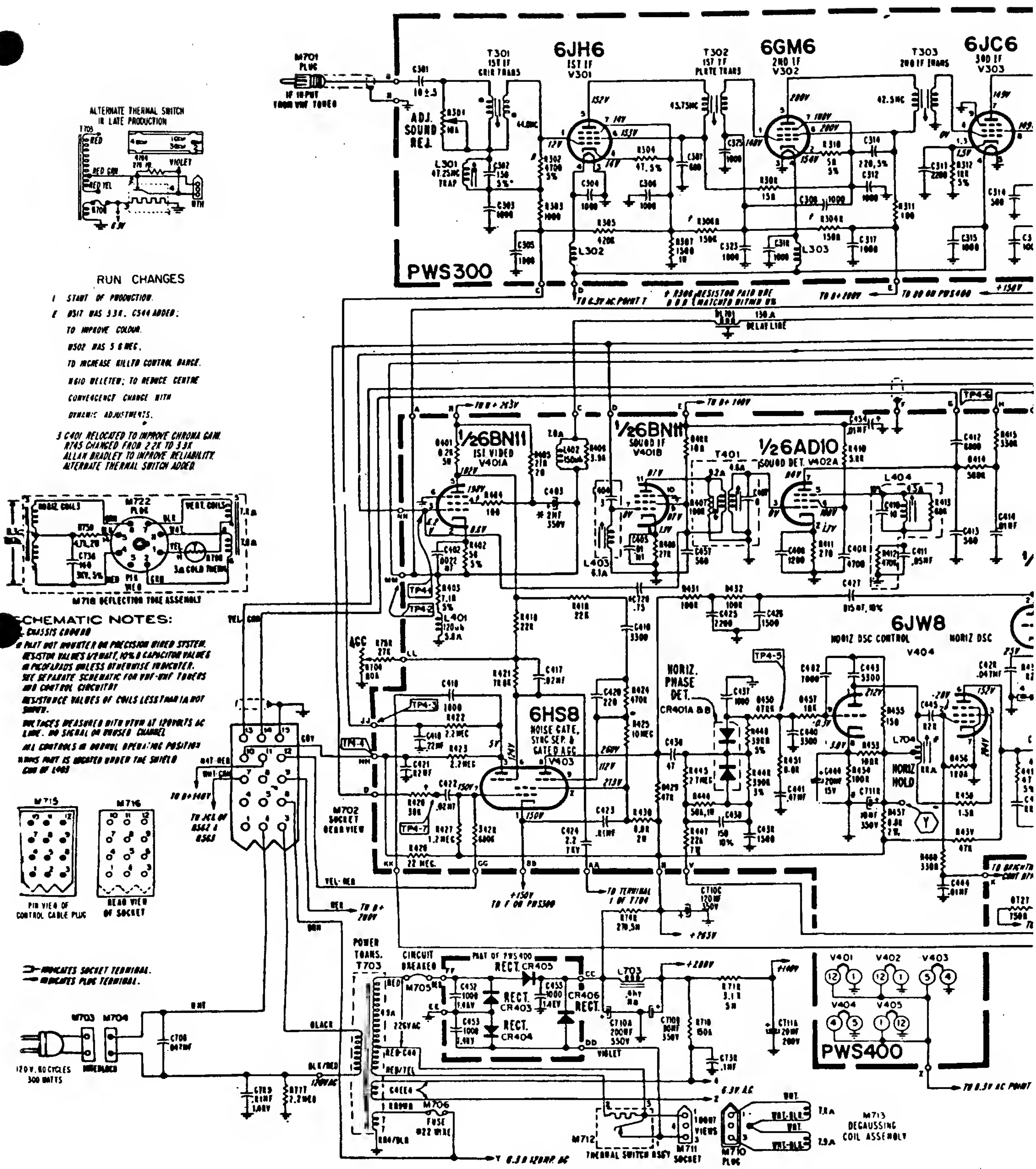
THE COLOR TV SET

EXHIBIT A-1



THE ELECTRICAL CIRCUIT AND PARTS

EXHIBIT A-2



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SCHEMATIC OF COLOR T.V. CIRCUIT

THREE PROBLEMS IN PRODUCTION DESIGN

B. The TV Knobs Problem

Background

Two engineers were involved in a crash program to solve a problem concerning the knobs on a TV set. The problem was not an engineering one of great complexity, but rather it was like one of the many small technical problems that engineers must deal with. It taxed their problem-solving skill.

The problem solvers in this case were Bob Jones and John Jenkins. They were part of the engineering staff of a middle-sized electronics company in a middle-sized North American city. The company had annual sales of $25,000,000, of which $15,000,000 was in TV products.

 Prepared by Sidney F. Love with support from the National Science Foundation through the Engineering Case Program, Design Division, Department of Mechanical Engineering.

One of the key policies of this company was to make better quality products than their competitors. This policy permeated the whole organization from engineering to sales. If a dealer made a complaint, it was investigated by a salesman. He in turn might call in a Quality Control representative. Frequently engineers were also called on to investigate dealer complaints. As a result, everyone was complaint-conscious. The mere thought of a rash of dealer complaints, however trivial in the technical sense, sent the organization into a near panic. Occasionally a dealer would complain directly to the president, who in turn would demand immediate action. This tended to reinforce the actions of those who got jittery at the thought of a dealer complaint.

A business must operate at a profit if it is to continue, and quality has its price. To offset the tendency of high quality to increase the cost of products, the organization was also very cost-conscious. A ten cent increase in the cost of a $100 product was significant. They might easily make 20,000 units and the gross change in profit would be $2,000.

This type of organization made a net profit after taxes of only 5 per cent. A cost increase of $2,000 was equivalent to about $40,000 additional sales, assuming that the selling prices did not change.

John Jenkins was the manager in charge of the engineering of the TV products. He had an engineering degree and was licensed to practice engineering. He had been involved with electronics design for fifteen years. For the past year he had been responsible for also managing the mechanical design of the TV products. Like many engineers, he regarded himself as an excellent problem solver.

In keeping with his status in the company, he always wore a white shirt and a bow tie. When he went to meetings he wore his suitcoat. He kept his desk tidy and only employed good-looking secretaries.

Bob Jones was mainly self-educated in mechanical engineering. He was employed as an engineer even though he had not been formally trained as one. When he had finished high school, he had gone to work for a firm which made metal office equipment. Over a twelve-year period, he had worked his way up from draftsman to mechanical designer. He had worked for several other manufacturers and, as a result, was very familiar with shop practices for sheet metal, die-casting and plastic molding.

The Problem

At 10:00 A.M. on a Monday, Bob Jones was contacted by the Quality Control Manager. He was told that Quality Control would not permit shipment of the newest TV model unless the knobs were changed. An inspector had decided that the on-off volume control was too hard to turn. In the words of the Quality Control Manager, "A child would not be able to turn the set on. This could result in a rash of dealer complaints."

"Oh, boy," thought Bob, "the fat's in the fire now. We have put $10,000 worth of tooling into this new model and it had better be good. The Styling Manager demanded

those long, tapered knobs to give the TV a modern look" (see Exhibit B-1).

Bob walked out to the factory floor and asked the inspector to let him try out one of the knobs.

The Diagnosis

Bob got a TV set and tried out the knob himself. He thought: "The knob doesn't turn. . . .that's in the past. We want to accomplish turn-on. So what is the key obstacle? Switch torque? I'll have the switch torque measured later. Meanwhile I'll try a larger knob on the control. . . .The larger knob seems okay, so the torque probably is not too great. What else could be wrong? Is the side of the knob binding on the cabinet? I'll try it. No sticking, therefore no binding problem. Is the knob too small? Does anyone else use a small knob? . . .Yes. Therefore, the knob diameter is probably okay. What else? Try to turn knob as a child would. My fingers slip. Is the surface too smooth? Compare with competition's knob. Theirs works. It is less slippery and the taper on the knob dips in so that more of the finger is in contact. (See Exhibit B-1.) So ours is slippery? I'll add masking tape and try it. . . .It's okay now. Why don't the splines work? Are the splines too rounded before or after metallizing? Who caused the problem? Engineer? Vendor? Stylist? Wait a minute! This is not related to what we want to accomplish. Better consider that separately. What is the problem now? I'll try a trial diagnosis." On his note pad he wrote:

We wish to have the on-off volume knob capable of being turned on by a child's hand and the key obstacle is the small, slippery knob.

"I suppose a larger knob is the answer, but the Styling Manager wouldn't like that. Hold on! Here I am trying to get a solution and I need to set the criteria for a good solution first.

What are they? Time is one, because the product is behind on delivery. Break the problem into: (a) a solution for tomorrow's production starting at 7:00 A.M.; (b) a long-term solution for future production runs.

Another criteria is cost. Say 25 cents per set as an upper limit. It also needs the Styling Manager's approval. Must be long-lasting to live up to company's reputation. Must be replaceable by the standard service part. Now, try the statement of diagnosis."

We wish to accomplish turn-on of on-off volume knob by a child's hand. Key obstacle is probably the slippery surface of the small-sized knob. A good solution must be ready by 7:00 A.M. tomorrow, look good to Styling Manager, be reliable, replaceable, and cost less than 25 cents per set."

The Solution Phase

Bob went upstairs to see his boss, John. They discussed the problem.

John: "It seems to me that the obvious solution is to replace the knob with one of the proper design, but I don't see how that could be done on time."

Bob: "Well, hold on a minute. I'm not too sure how long it would take. All we might need to do is cut a sharper edge on the spline and if we didn't require a highly polished job, it could be ready by tomorrow. Let me call our vendor and see just how long it would take in case we don't find another solution by tomorrow morning."

John: "Okay, but let's see if we can get a few more possible solutions first. We could replace the knob with one from another set, but then it wouldn't match the others."

Bob: "Sure, but why not replace the others too, then we could have a matching set. I think we could get some off the 'Fidelity' model we made last month. There probably are some knobs in stock."

John: "Yes, but what would the Styling Manager say?"

Bob: "Let's cross that bridge when we come to it. Meanwhile, I'll get a couple of knobs out of stock and put them on sets and see how they look."

John: "Before you go, Bob, let's try again for more solutions. I'm really not satisfied with anything we've got so far. It's been my experience that if we get working on the first solution that comes to mind that we forget to look for better ones."

Bob: "You're right."

John: "I wonder if we could roughen up the surface a bit so that it wouldn't be so slippery? I suppose that would never get past the Styling Manager."

Bob: "Well, maybe. What about having some knobs made without the metallizing. I think they would be a lot less slippery."

John: "Yes, but do you think they would approve white knobs instead of chrome."

Bob: "They needn't be white. We could get them molded in black, say, and I think that would look quite good."

John: "Okay, that's a possibility. Will you check that with the vendor when you call him?"

Bob: "Okay. Now, the knob works better if you put a piece of paper tape around it and increase its diameter."

John: "But the tape looks like hell."

Bob: "How about some colored plastic tape or maybe some silver-faced tape. It would look shiny like the knob."

John: "The tape would come off and be unreliable. . . .Suppose we take a hot tool and make a ferrule on the end of the knob. No, I guess that wouldn't look very good, but we could roughen up the surface with a hot tool."

Bob: "Yes, and I also could make the tape stick permanently. (Pause.) We seem to be running out of ideas. I suppose we could get the switch torque reduced to a lower value and replace all the controls, but that would be costly and take a few days at least. I'll have someone call the control vendor anyway and see what the fastest delivery would be on the lower torque switch. Oh! I just remembered. If the torque is too low, the contacts get dirty because there is not enough pressure to wipe them clean."

John: "If we could just get some of those knobs that our competition uses, they wouldn't be too bad, but I suppose that they would never let us use them."

Bob: "Well, maybe it's not their knob anyway. Perhaps the mold belongs to Universal Plastics who make knobs to their own designs to sell to the industry."

John: "Well, you could check it out but I don't think there's much hope there." (Pause.)

Bob: "Well, I'm out of ideas and I'd like to get working on the ones that we have."

John: "I'm out of ideas too, and yet I feel there ought to be a better solution. Look, I've got something important to do in connection with another problem. Suppose we meet again in another half hour after you have checked some of these things out. I'd like to mull this problem over a bit."

(Three-quarters of an Hour Later)

John: "Hi, Bob. The Production Manager has been burning my ear off about having production stopped. If we don't get this fixed soon, I think all hell's going to break loose. Somebody's head will roll."

Bob: "Yes, some people think that we're supposed to come up with perfect designs. They ought to try it for a change. I checked the drawing out on this one so I guess I'm partly responsible."

John: "And I had those splines put on, just to make sure there would be enough grip so I'm partly responsible too. Still I think the vendor did a lousy job because this isn't nearly as good a gripping knob as the hand-made sample we supplied."

Bob: "Maybe it was the Styling Manager's fault. After all, he . . . ."

John: "Let's forget what's going to happen if we don't solve the problem, and see how we're doing anyway."

Bob: "Well, I called the vendor of the knobs and he said he could rework two cavities in the mold and plug up the rest in about two days. However, he says that since the metallizing is done in another plant there would be at least another day's delay in finishing, even if we moved them about by taxi."

John: "Okay, three days for that solution. Anything else?"

Bob: "New switch controls could be obtained with a lower torque three days after our approval of the sample. So that would take about a week overall. The new controls plus the rework costs would run about $1.00 per set because they would have to remove the chassis to work on the control panel."

John: "What else, Bob?"

Bob: "Well, I checked the drawing on the other knobs which we might substitute and find that they won't fit the shaft, so I saved myself a trip down to the stockroom. I found out that Universal Plastics are shut down because they are on strike. We are trying to reach the salesman at his home by long-distance telephone."

John: "Well, so far we've only drawn blanks. Let's try looking for some more solutions. You know, the Hi-Fi group had a similar problem but they caught it in the design stage. They put a little ferrule at the end of the knob."

Bob: "Well, we could heat-swedge one on with a molding form if they weren't metallized."

John: "Yes, or we could take another piece of plastic and glue it on the end and then have it metallized."

Bob: "Yes, or we could have a special piece of plastic made up which slipped over the end, like this." (Bob draws it on a piece of paper.)

John: "I think you've got something there. Now let's suppose we had a small plastic sleeve fitting over the end of the knob, which would increase the diameter, say, about 1/16th of an inch overall. I wonder how that would be for torque?"

Bob: "It wouldn't be too bad if the plastic wasn't the slippery type." (Pause.)

John: "Look, Bob, would you mind if we brought Gary in. He's worked on plastics quite a bit. Maybe he could help us."

Bob: "Fine with me."

(A few minutes later.)

Gary: "As I understand you, it's difficult to turn the switch on because the end of the knob is small and slippery."

Bob: "That's about it, and then we thought that if we could make the end larger by cementing another knob to it like you did on the Hi-Fi, we could overcome the problem. I don't think we could do that in time. If I put a piece of tape around the end, it works okay but looks bad."

John: "What about those plastic caps that go on the end of tubular chairs and wire furniture? I've seen them down at the hardware with as small a diameter as 1/4 inch."

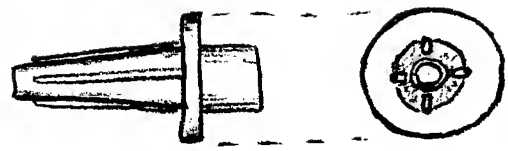
Gary: "They come in even smaller sizes than that because I've seen them down at the vendor's place. He probably supplies them to some specialty manufacturer."

Bob: "We would need a size with about 7/32 inch inside diameter if they are going to fit tightly over the splines. And the outside diameter should be considerably larger."

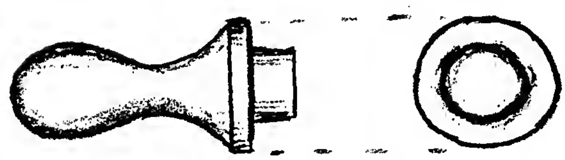
Gary: "I'm pretty sure the vendor has them in various sizes. He may not have the color we want but some more could be molded by early tomorrow."

John: "This looks good. I think we're getting close to a good solution now. You fellows consider the other criteria of a good solution while I get the vendor on the line here, and we'll know the answer within a few minutes."

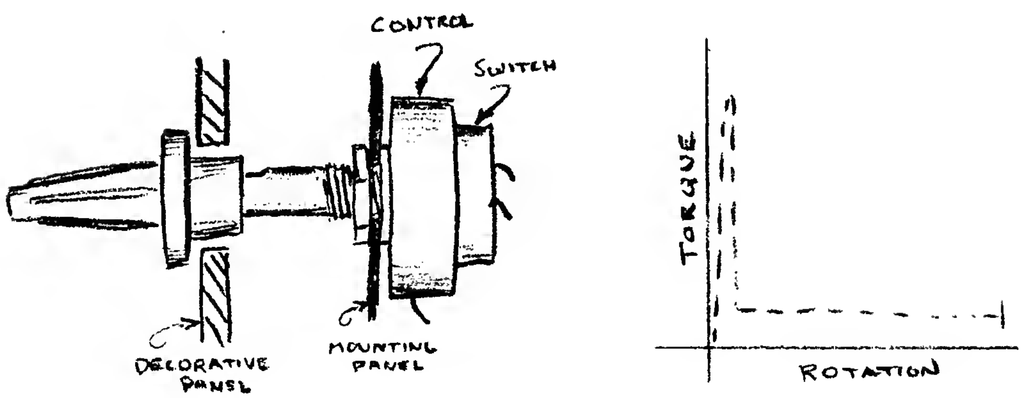
The short-term solution is shown in Exhibit B-2. The long-term solution of deeper splines is shown in Exhibit B-3.



THE PROBLEM KNOB



COMPETITION'S KNOB

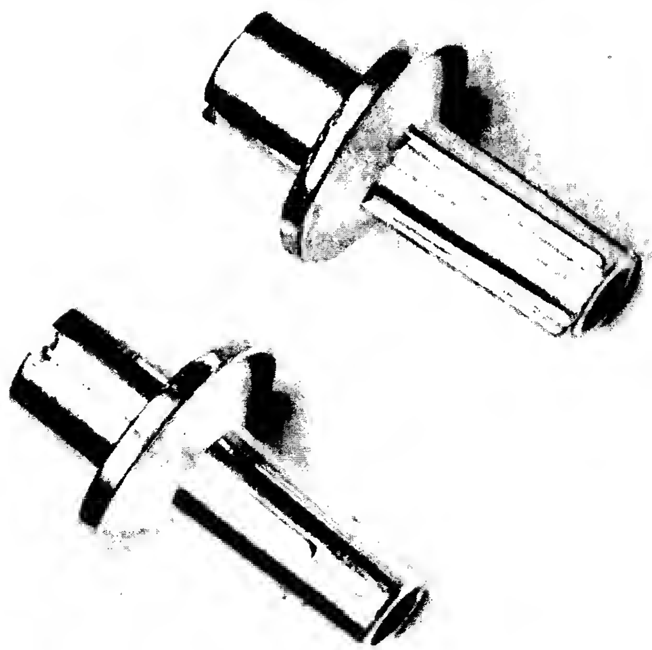


KNOB, CONTROL AND SWITCH ASSEMBLY

EXHIBIT B-1

SHORT-TERM SOLUTION

EXHIBIT B-2



LONG-TERM SOLUTION

EXHIBIT B-3

THREE PROBLEMS IN PRODUCTION DESIGN

C. The Extra Holes in the Metal Cabinet Problem

The Company, Products, Facilities and Engineering Department

Apex Electronics Limited made about 10,000 television sets per year. Their product policy was to give their retail dealers an exclusive range of good-looking merchandise.

More details about Apex can be found in the case study of Part A: *"The Radio Interference Problem".*

Background

The Apex engineers involved in this case had been attending a Problem-Solving course taught be their consultant, Ralph Smith. They had done several practice problems in class and were quite aware of the value of defining: "what is to be accomplished," "the key obstacle," "finding alternatives," etc. The mechanical engineer, Salvatore Lundi, had told Ralph that he was enthused about the course. He had previously considered himself to be a good problem solver, but got "all shook up" in the first session when he noticed that other members of the class were doing better than he in diagnosing a practice problem. "Now I want to learn more about good problem solving," he had said to Ralph. This and other comments encouraged Ralph to continue the course but he was still uncertain of the overall results. Fundamental to the method he taught was for the problem solver to write out a problem statement. Yet none of the engineers or technicians seemed to be doing this. Jim Jones, the Hi-Fi technician, had used the step-by-step method to solve an acoustics problem at his church, but still did not use it at his work. Ralph concluded that old habits were going to be hard to change.

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The Principals In The Case Study

Ralph Smith, the consulting engineer, was about forty-five years old. He was a university graduate and had practiced as an electronics engineer for about twenty years. He had been involved in many television designs, including color television, which was new to Apex.

Peter Brutowski, at thirty-nine, was a self-made man. He had finished high school but had not gone on to college. In the Air Force, he had been trained as an electronics technician. After his military service, he worked for a while as a television serviceman in the Apex factory. Because he was found to be better than the average technician, he was picked to help the chief engineer in the laboratory. A few years later, the chief engineer had died suddenly and Peter had taken over the designing position. Since then, he had designed several successful black-and-white television sets and Hi-Fi sets. He was now recognized as an engineer by Apex because of his ability to do the work.

Allan Miller, at twenty-eight, was the chief engineer, in charge of the design of television and Hi-Fi products. He was a graduate electrical engineer and had about four years' practical experience in the television field.

Salvatore Lundi, at fifty-one, had been with Apex all of his working career. He had learned about sheet metal work, die casting and plastics from working as a mechanical draftsman. As the company expanded, Salvatore became the senior draftsman, and was currently in charge of all mechanical design for television and Hi-Fi products. He had two draftsmen reporting to him. Salvatore reported to the chief engineer, Allan Miller.

Jim Jones was a former Air Force electronics technician who received a medical discharge after his hearing was impaired by aircraft noise. He had joined Apex at the age of twenty-eight, and two years later was regarded as a specialist in record changers and radio speakers.

The Problem

A 19" TV model had a rectangular metal cabinet made from vinyl-clad steel. The holes were punched out of the vinyl-clad steel while the metal was flat, and then it was bent into shape. (The vinyl was not damaged by this process.) Five hundred cabinets in a wood-grained color were madeup with three extra holes in one side. This was due to a misunderstanding about which model was to be made (Exhibit C-1). At the start of the scheduled production run of chassis using these cabinets, the error was discovered. A solution was requested to be available for use within one day.

Prior to attacking the problem in a formal way, metal plug-buttons (Exhibit C-2) were suggested and samples were made up for one cabinet. As a previous stock of plug-buttons had been scrapped, approximately 1,500 new ones were ordered to come in the same day by bus. The first ones were ordered as 7/16" and this was corrected to 1/2" before the actual shipment was made. Some persons were not satisfied with this solution from an appearance point of view, although it appeared that the time criterion could be met.

The Situation

The next morning when Ralph came in, he saw most of the small engineering staff standing around the portable TV set. Allan Miller, the young chief engineer explained the problem. "None of us like the appearance of these plug-buttons. Even when painted brown to match the wood-grain, they don't look right. What would you suggest?" Ralph looked around at the five people. They were just making conversation. Nobody was seriously looking for a new solution. They waited for some words of wisdom from their consultant.

"Let's try to solve this together," said Ralph, picking up a note pad. "For a beginning, how about a written diagnosis. What would you say is to be accomplished?"

Ralph kept his notes visible so that the others were able to review what was written down. They did this several times.

The following is from Ralph's note pad:

What is to be accomplished?—cover up holes? make a saleable set? (two points of view).

What is the key obstacle?—holes in 500 sets.

What are the criteria for a good solution?—appearance, one day's time, cost, reliability.

Statement of Diagnosis: (not made).

What are some alternatives? Suggestions made by the group of five persons were in the following order:

1. Plug-buttons with painted finish. (Ralph)
2. Decorative horizontal strips covering the holes. (Peter)
3. A decorative escutcheon covering the holes. (Salvatore)
4. Decorative vertical strips on side and across top. (Peter)
5. A nameplate. (Allan)
6. Triangular trim on side, about 6" x 10". (Peter)
7. Do nothing. (Peter)
8. Dummy knobs. (Jim)
9. A patch made from the same color of vinyl-clad steel. (Salvatore)

10. Make new cabinets and use present ones on a later model. (Jim)

11. Modify TV chassis to one with three controls at side. (Ralph)

12. Use present cabinets on a later model by punching the extra hole needed in the top. (Salvatore)

13. Cover holes with decorative wood strip to match vinyl. (Peter)

14. Vinyl-clad steel with rolled edges, and stuck on with double-sided foam tape. (Salvatore)

15. Brown plastic buttons. (Jim)

What are the Advantages and Disadvantages of Some of the Alternatives?

Alternative	*Advantages*	*Disadvantages*
Plugs (No. 1)	–fast	–Sales objection to appearance –Painted vs. grain of cabinet –May rattle –May get chipped
Make new cabinets (No. 10 and 12)	–no scrap –no rework	–Alternate work needed for production personnel –Overtime charge –Set-up time–a delay
Vinyl-clad steel (No. 14)	–fast –grain matches –edge is grained	–May not stay on

Other alternatives were not analyzed in detail. More information was needed to make a decision.

What would No. 14 look like? A sample with rolled edges was made up and found to be thick in appearance. A modified version (see Exhibits C-3 and C-4) was made up and stuck on with double-sided adhesive foam tape.

Which Alternative?

Top management was presented with three alternatives:

1. Painted plug-buttons (previously tentatively approved without seeing a sample).

2. Make new cabinets.

3. Vinyl-clad steel patch.

The painted plug-buttons were judged poor in appearance and risky in execution.

The new cabinet approach was discarded because it would take a week to set up and make them and this was too long.

The vinyl-clad steel patch was chosen because of the acceptable appearance. speed and low cost of the solution.

End Result

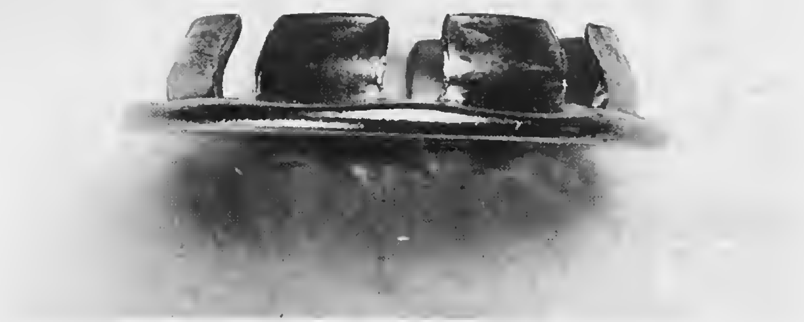
The solution chosen was satisfactory from a production point of view.

The surplus plug-buttons were put into reserve stock. Their value was only about $45.00 as they were unpainted.

METAL CASE
WITH 3 HOLES
AT SIDE REQUIRED
FOR THIS MODEL

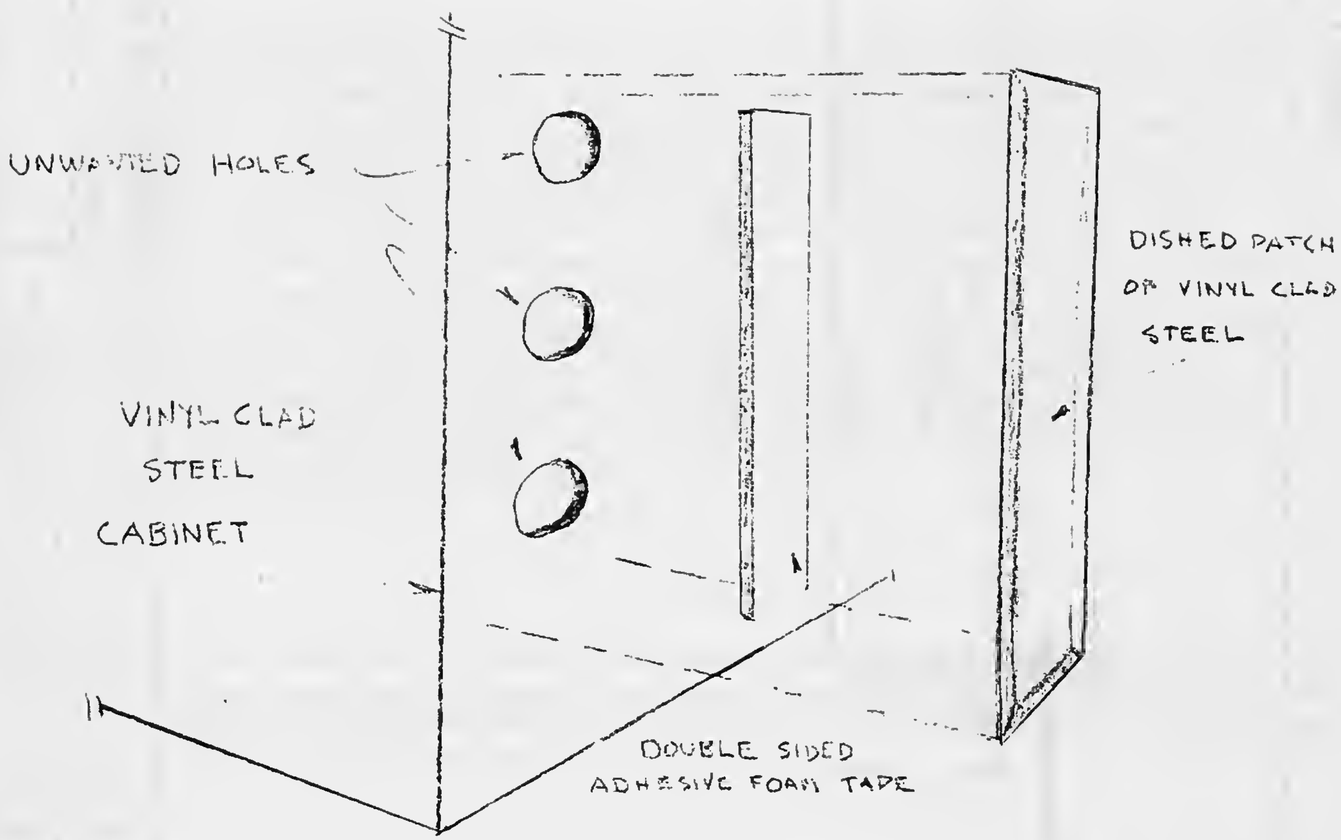
THIS MODEL
DID NOT REQUIRE
THE 3 HOLES AS
THE 3 CONTROLS
WERE AT THE REAR.
(HOLES OR PATCH
NOT SHOWN.)

EXHIBIT C-1



A PLUG BUTTON
(5 TIMES FULL SIZE)

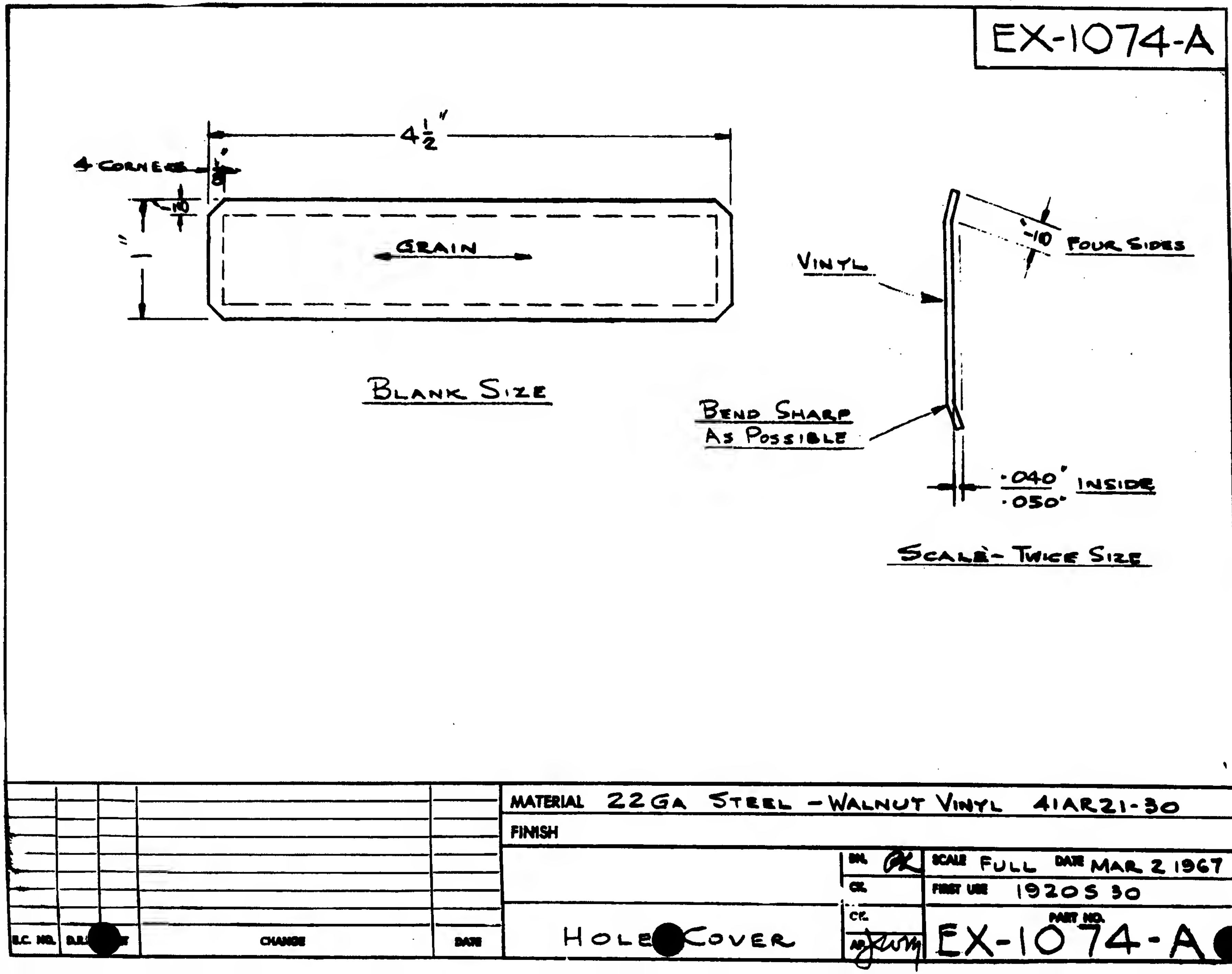
EXHIBIT C-2



THE SOLUTION

EXHIBIT C-3

EXHIBIT C-4



EX-1074-A
4 1/2"
4 CORNERS 1/8"
.10
1"
GRAIN
BLANK SIZE
VINYL
.10 FOUR SIDES
BEND SHARP AS POSSIBLE
.040" .050" INSIDE
SCALE - TWICE SIZE
MATERIAL 22 GA STEEL - WALNUT VINYL 41AR21-30
FINISH
SCALE FULL DATE MAR 2 1967
FIRST USE 1920S 30
PART NO. EX-1074-A
HOLE COVER
E.C. NO.
CHANGE
DATE

ECL 108D

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THREE PROBLEMS IN PRODUCTION DESIGN

D. Methodologies of Problem Solving and Designing

Note

The following discussion of problem-solving methodology was originally intended as a preface to cases ECL 108A, B, and C. It is printed separately, however, because some teachers may prefer to use the cases without specific reference to this methodology.

Problem-solving methods are not new. Famous philosophers and other great men have written down their recommendations.(2) However, it is only in modern times that problem-solving has been organized into a systematic method. Contributing to this were the Scientific Method, Statistics, Decision Theory, and Modern Psychology.

Problem-solving methods have been found which fit quite well to those used by good problem solvers. This has been shown through analysis of the methods used by problem solvers and designers.(9, 10) As there are variations in the way people think, so there are variations of the basic method. It also varies with the type of job to be done. However, there is a general pattern underlying them all.

The problem-solving method described in detail herein is oriented towards engineering and industry. It will blend into methods for design. Designing is an elaborated extension of problem-solving because more effort is usually put into analyzing the need, defining the design problem and in implementing the resulting design.

It is convenient and advantageous to learn problem-solving in four steps before learning a more complicated procedure such as an eight-step designing method. A "problem," be it technical, personal or social, is usually thought of as a disturbance to the previous environment, and as such is easily recognized and defined. A design, on the other hand, is intended to change the environment to some new state. Thus, when designing, it is customary to make a more detailed analysis of the present and future environments than one does for a "problem." An understanding of the simplified "problem" solving process is a worthwhile prelude to learning more about designing. It is also immediately useful in solving everyday problems.

Problem-solving is something one learns early in childhood and, like walking, one does not think about the method. It has become habitual. It would be hard for one to permanently change his walking technique. Likewise, one's problem-solving method has become habitual and is hard to change. For a new method of problem-solving to be adopted, one must try out the new method and find out that it is better. This develops internal motivation to use the new method. In the following studies, one vicariously becomes a problem solver without the risk of a real problem situation. The case studies are outside the regular routine of the student. This helps break up old patterns of problem-solving by putting the student in a new context. Even an expert problem solver, after he becomes aware of his method, can become a better problem solver. However useful a case study may be in developing understanding of a method, the student should realize that he must practice the method himself before it becomes habitual.

2. *Problem-Solving Steps*

From Newman and Summer, [1] there are four steps, namely:

1. Making a diagnosis.

2. Finding alternative solutions.

3. Analyzing and comparing alternatives.

4. Selecting the plan to follow.

From Fig. D-1, you will see that this is similar to other recommended methods of problem-solving. In its full expansion, it will cover all the important steps in any of the methods. Fig. D-2 is a summary of the design steps of several authors on design methodology and Fig. D-3 is a comparison of problem-solving and designing.

STEP 1: MAKING A DIAGNOSIS (IN DESIGN: NEEDS ANALYSIS, DEFINITION OF THE PROBLEM AND ESTABLISHMENT OF CRITERIA)

Newman and Summer (1)	John Dewey (2)	Timms (2)	Drucker (3)	Wright (4)
			Defining the problem.	To recognize the problem.
Making a diagnosis.	What is the problem?	Identification and definition of the problem.	Analyzing the problem.	To get all the facts.
Finding alternative solu tions.	What are the alternatives?	Identification of alternative courses of action.	Developing alternate solutions.	To classify and arrange the facts.
Analyzing and comparing alternatives.	Which alternative is best?	Assessment of all factors entering into each course of action.		To arrive at a trial solution--To test the trial solution.
Selecting the plan to follow.		Choosing one of the alternatives.	Deciding upon the best solution.	To adopt a final solution.
			Converting the decision into effective action.	

PROBLEM-SOLVING METHODS

FIGURE D-1

FIGURE D-2

A COMPARISON OF SYSTEMATIC DESIGN METHODS

Handa, Roe & Soulis

- Defect or lack in environment
- Need analysis
- Definition of the Design Problem
- Development of Design Criteria
- Development of Alternative Solutions
Analysis of Feasibility
Optimization
- Selection of solution to be used
- Implementation and Communication
- Rectified defect or
Transfer to more detailed phase

Hall

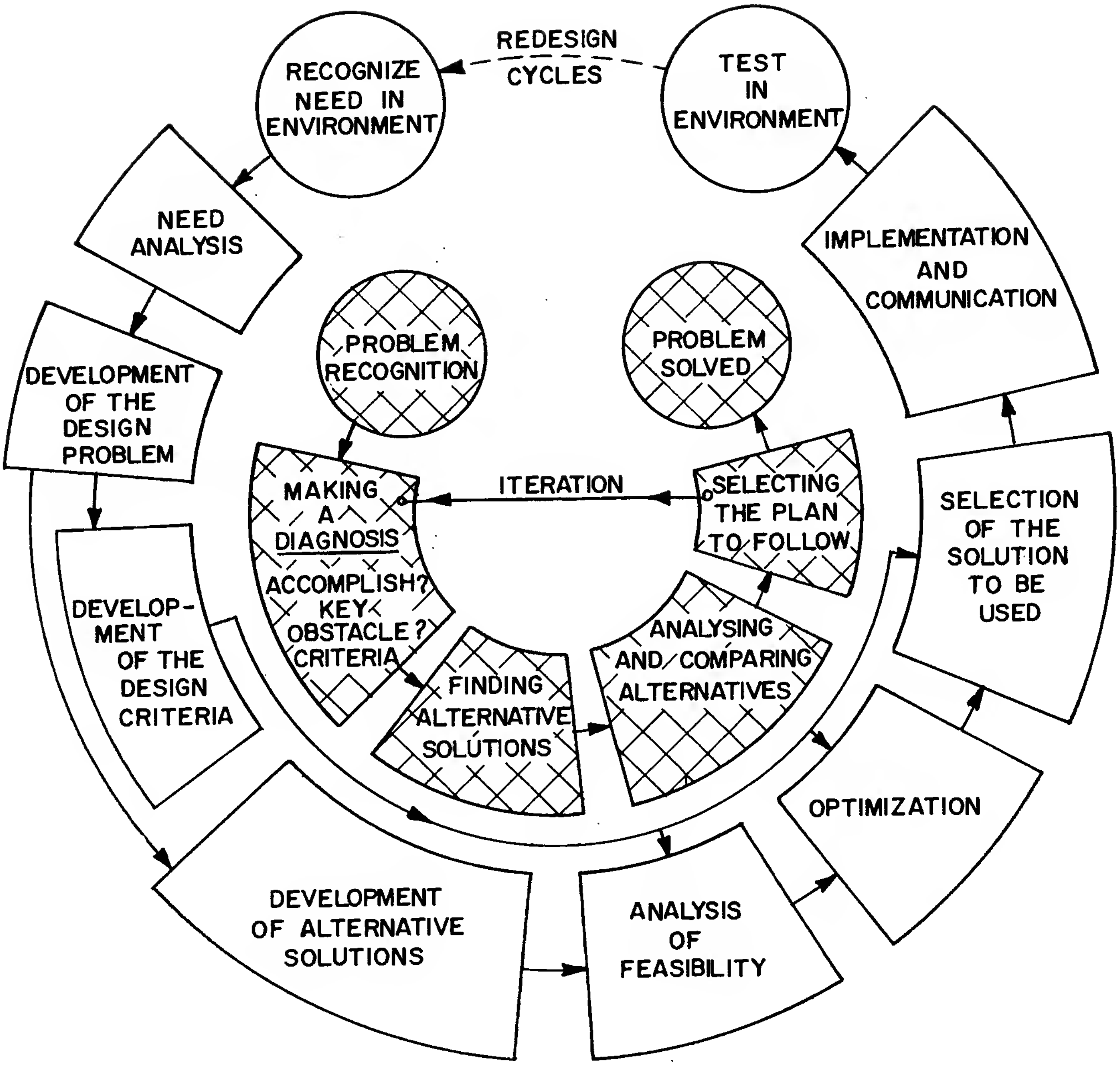
- System Studies (Programme Planning)
- Problem definition
- Selecting Objectives
- System synthesis
System analysis
- Selecting the best system
- Communicating Results
- Transfer from Exploratory Planning to Development Planning, then to Studies during development, then to Current Engineering

Asimow

- Analysis of the Problem Situation
- Synthesis of Solutions
Evaluation and Decision
Optimization
Revision
- Implementation
- Three phases are:
Feasibility Study
Preliminary Design
Detailed Design

Buhl

- Recognition
Definition
- Preparation
Analysis
& Synthesis
Evaluation
- Presentation



PROBLEM SOLVING AND DESIGNING

FIGURE D-3

This is a step that should end with a written statement of the diagnosis which contains:

–just what you wish to *accomplish* (what's done is done and for the time being it is better to forget about the cause).

–the key obstacle to the accomplishment (the real problem, which may not be the cause of the present situation).

–criteria for a satisfactory solution (criteria such as finances, specifications, human relations, etc.).

–restraints on a solution.

–for a very complex problem, a division into sub-problems.

Use the Scientific Method of Analysis to help define the key obstacle, i.e., Hypothesis-Test-Revise. See p. 3 of the TV knob case for an example of this technique.

STEP 2: FINDING ALTERNATIVE SOLUTIONS (IN DESIGN: THE DEVELOPMENT OF ALTERNATIVE SOLUTIONS)

–use past experience.

–consult others on their experience.

–record what others do.

–create new solutions by self.

–create new solutions with a group.

The number of alternatives depends on the problem. Two is a minimum (do or not do). Just to get a rough idea, we can quote one experienced engineer who says that he likes to see seven for average, and more than seventeen if no known solution exists. This may seem like a lot, but most engineers tend to err in not generating enough alternatives. Quantity alone is not enough. Some of the alternatives should be novel. The same engineer says that if he does not have some alternatives that are too novel to use, he feels that he has not got enough alternatives.

STEP 3: ANALYZING AND COMPARING ALTERNATIVES (IN DESIGN: ANALYSIS OF FEASIBILITY AND OPTIMIZATION)

–list advantages of each.

–list disadvantages of each.

–examine long-term consequences of each (What will happen if the solution is used?).

–what is the difference in results of each alternative?

–will the solution meet the criteria and restraints established in the diagnosis?

STEP 4: SELECTING THE PLAN TO FOLLOW

–does statement of diagnosis need changing? (iteration).

–eliminate some by applying crucial criteria.

–risk factor comparison (What chance of success?).
–emotional factors affecting implementation (like resistance to change).

–implementation plan (what, where, when, how, why and who?).

3. *Cyclic Repetition Of Steps*

Many problems and designs benefit from a cyclic repetition of the steps of a systematic method. This is because:

–as the problem solution (or design solution) progresses, more information is gathered. This makes it advisable to review the previous decisions.

–manpower, time and financial resources are limited. One needs to frequently review the probabilities of a successful solution.

The cyclic nature of problem-solving is not always recognized. If the first cycle does not give a satisfactory solution, the tendency is to return to the step of Finding Alternative Solutions. It is advantageous to return to the beginning and review the diagnosis (as is shown in Step 4). Frequently, the problem will look quite different because of the additional information gathered since making a statement of diagnosis.

4. *Iteration*

At any point in any cycle or step of a problem-solving process, it may be advisable to return to a previous stage. This is called iteration. For example, when the criteria for cost cannot be met after a large number of alternative solutions have been analyzed, it is not uncommon to return to an earlier step (iterate) and revise several of the criteria. This usually occurs and is different from a formal cyclic repetition of all of the steps.

In the problem-solving method discussed, a recommended iteration was from Step 4 back to Step 1. Others are possible as new information changes the perception of the problem.

5. *The Variables In Problem-Solving*

Results in problem-solving need not only technical skill, but also good methodology in using this skill. The results are a function of both.

Technical Skill Required of Problem	X	Method of Problem Solver	GETS ⇒	Results

VARIABLES RELATING TO THE PROBLEM

Technical skills required.

Complexity of problem.

Size of problem.

Novelty of problem.

VARIABLES RELATING TO THE PROBLEM SOLVERS

Methodology used.

Problem or solution orientation.

Assumptions made.

Creative ability of self or of a group.

Skill in working with groups.

PROBLEM ORIENTATION VS. SOLUTION ORIENTATION

Most people are solution oriented when solving a problem. From a vague problem statement, they think of ways to fix the problem fast. This is not surprising. Industry rewards the man who solves the problem fast.

The quick-thinking person who acts fast is the popular idol of screen, magazines and politics. The intellectual who wants to examine the basic problem is frequently scoffed at. Modern society puts a premium on quick action to solve problems, be they industrial, political or social. This is solution orientation.

In a primitive situation, fast problem-solving is essential to survival. It is still essential today for the simple task of crossing a busy street. However, in technical problem-solving, taking time to size up the situation and develop alternatives is more appropriate than quick action. This is a problem orientation.

A problem orientation is said to be more helpful in problem-solving. This is a search for defining the problem and a search for solutions until one is found which solves the problem well, even if it takes more time.

ASSUMPTIONS

All problem-solving begins with some assumptions about the reality of the situation because it is nearly impossible to know all of the facts. A good problem solver will classify his data into assumptions and facts insofar as it is possible. Attaching probabilities to the data is a further step in clarifying data.

The most difficult assumptions to identify are those which are implicit in the situation and are not verbalized. They may be a weak foundation from which to solve a problem. Identification of the assumptions is good practice, even if there is no alternative but to proceed as if they were true.

6. *Review Questions On Methodology*

1. What differences do you think there are between technical problem-solving and designing?

2. What similarities?

3. Where would you find relevant information for finding alternatives for a problem with a neoprene seal between the drill and casing of an oil well drilling rig?

4. In general, what are some sources of alternative solutions?

5. Think of one professional problem solver whom you know well, such as an engineer, doctor, dentist, lawyer, professor, etc. Was he or she problem or solution oriented in a case you remember? Why?

6. Is the Problem-Solving Method shown here appropriate for a student to solve a non-technical personal problem?

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INSTRUCTOR'S NOTE

for

THREE PROBLEMS IN PRODUCTION DESIGN

Subject Of The Case Studies

These cases deal with problem-solving as a human activity. The characters are reconstructions of real people solving real problems. Some do it well and some do not. By examining their behavior and comparing it with the theory, one is better able to understand the principles of problem-solving. This is done in action situations, involving both individuals and groups.

The problems were actually faced by engineers. However, their method, not their technology, is what is emphasized. Therefore, students in any discipline may use the case studies. They have been used with mechanical, electrical and civil engineers, architects, graphics designers, industrial designers, technicians and machinists.

The case may also be used to emphasize the Human Factors in Engineering by questions like:

1. How would you find out the amount of torque to specify for the switch, if the original knob is still to be used?

2. What are the variables in the system of switch, knob and child?

The Sequel

The plastic caps were glued onto the knobs for the current production run. When the model was produced again, knobs of the new design (Exhibit B-3, long-term solution) were used with entirely satisfactory results.

If a dealer ordered a replacement knob by part number or model number, he was sent two of the new-style knobs because they were used in matching pairs. This, however, was only realized after a single replacement was sent out and a dealer complained of the difference.

Part C: A Case Study—"The Extra Holes In The Metal Cabinet"

The specific teaching objective of this part is:

—that the students develop more understanding of the steps for Finding Alternative Solutions, Analyzing and Comparing Alternatives and Selecting the Plan to Follow.

The following questions are only suggestions. They can be selected to focus the discussion on some particular aspect of problem-solving. They were tested in classrom situations.

Question 1

Q. To what extent was a formal problem-solving procedure followed?

A. In this case we see an attempt to use a formal method. The diagnosis is weak but the alternatives are well handled. More of the alternatives may have been analyzed and compared, but the pressure of time has probably limited the analytic effort. Some students may feel that the method of making the final decision by submitting it to the president was not part of a formal method.

Question 2

Q. Did application of the formal procedure contribute to the final solution? What case data supports your answer?

A. Since alternative 14 was the one finally used, and the plug buttons not used, we could reasonably attribute its finding to the method.

Question 3

Q. Did writing down alternatives contribute? If so, show how it did so from the case data.

A. Writing down the alternatives is something many problem solvers neglect to do. Solution 14 is related to 9 and 3. It is doubtful that memory alone would have carried 9 forward to 14. The problem solvers were able to review what was written down. Although not leading to the chosen solution, 1-8-15 is an interesting chain that is more likely to result from writing down the solutions than from memory recall alone.

Question 4

Q. Regarding the first solution of plug buttons, what did the people do that can be explained as being solution-oriented or problem-oriented?

A. The first solution of plug buttons was obviously the result of a solution-orientation. Even the wrong size plug buttons were ordered in the rush to have it solved quickly.

Question 5

Q. What effect do you think the presence of Allan Miller had on Salvatore's performance on finding alternatives?

A. This should bring out the point that Allan might inhibit his subordinate's performance. Also, there is the age and education difference. Young engineers should become aware of their effect on older practical designers. In this case study, there is no evidence that Salvatore is affected adversely. He created the solution himself. It looks like Salvatore has become a pretty good problem solver.

About one and one-half hours is required to read the case and discuss the above questions in small groups.

Additional Questions

This case is also suited to developing some understanding of the problems in training people in methodology. One may use such questions as:

1. Ralph concluded that old habits were going to be hard to change. Can you give some reasons why this may be true or not true?

2. In the Case Study, the group had a good demonstration of the value of using a problem-solving method. Is it still necessary for them to try it out individually before using it regularly?

General Teaching Objectives

1. To help the student understand problem-solving principles.

2. To give the student a procedure for solving his current problems, both technical and personal.

3. To develop a problem-orientation in the student.

4. To prepare the student for instruction in the methodology of design by first developing an understanding of problem-solving principles.

Additional Projects

One way to develop a fuller understanding of problem-solving principles is to assign them a real problem.

Individuals may be asked to use the method on one or more of their own problems and present a report on it. A convenient form is attached. It is recommended that some of these be given to each student. Class experience has indicated that some students do not understand the principles until they have applied them a few times to real problems.

Individual subjects may be personal or technical; such as:

–How do I get more time to study?

–How do I find the knock in my engine?

–How do I cut my living costs?

–How do I get more speed out of my motorbike?

Group projects may be on subjects of general interest to the whole class, like:

–How can we improve the layout of this room?

–How do we get more time for assignments?

–How can we reduce our costs of school supplies?

–How can we use problem-solving methods outside of class?

Part A: A Case Study–"The Radio Interference"

The specific teaching objective of this case is:

–that the students understand the Diagnostic phase of Problem-Solving.

The questions are not at all necessary for a group who have regularly done case studies. However, the instructor may select a few questions to guide a discussion group. The following questions were tested in classroom situations.

Question 1

Q. Which problem-solving step is illustrated by this case study?

A. The Diagnostic step is emphasized. They are attempting to find the key obstacle to the accomplishment of an interference-free TV set. They use the hypothesis-test-revise technique. Some students see the case as solution finding also. This helps clarify the meanings of diagnosis and the finding of alternative solutions. Some trial solutions are used in this case to help in diagnosing the cause.

Question 2

Q. Were Ralph and Peter problem-oriented or solution-oriented in this case study?

A. This is an illustration of problem-orientation, in so far as students see the case as diagnosis rather than solution finding.

Question 3

Q. Was Ralph's insight about rectifier radiation a sudden or gradual understanding?

A. The insight was sudden, but note that it only came after considerable mental work on the problem. For this reason some students will see it as a gradual process. This can be resolved by explaining that new relationships appear to come suddenly only after a period of work on the problem, although they may come in a relaxed moment later on.

About one and one-half hours are required to read the case and discuss the above questions in small groups.

Additional Questions

The case also has material to discuss some social and human problems. For example:

1. Ralph was trained at university and Peter was not. Should this make any difference in their problem-solving ability?

2. The president of Apex noticed the problem first. Suppose Peter had discovered it. Do you think it would have got the same attention?

3. Apex had a policy of giving exclusive dealerships in order to protect the dealer's profit. Was this ethical?

Questions like the above can be used to develop understanding of the industrial environment.

The Sequel

Apex Electronics is actually Sparton of Canada Limited in London, Ontario. Its president gave permission to reveal the company name.

What was done about the problem? The TV sets had been purchased from another manufacturer who subsequently claimed that the radiation was within the legal limits. Since not every customer would be concerned about the radio interference, it was decided to issue a field service bulletin which suggested a change of capacitors if the customer complained.

Part B: A Case Study—"The TV Knobs"

The specific teaching objective of this case study is that the students become familiar with the Problem-Solving step of Finding Alternative Solutions.

The following questions are only offered as a guide for discussion. They relate the case to the theory part and have been tested in classroom situations.

Question 1

Q. What are some differences between the approaches to problem solving of John and Bob, and what is good or bad about their approach? Were they problem-oriented or solution-oriented?

A. John is usually problem-oriented, that is, he seeks a lasting solution to the problem. Bob tends to be in favor of an immediate solution and is thus solution-oriented.

Question 2

Q. Bob suggested solutions and then John said why they won't work. What was the effect of this prejudgment of solutions on the total problem-solving time?

A. If you look at solutions 5 and 6 (paper tape or plastic tape on the knob), they were close to the final solution used. John criticizes ideas and Bob drops them. The effect of this prejudgment apparently was to lengthen the problem-solving process.

Question 3

Q. Can you show where one *idea* for a solution led to another idea?

A. The idea of a "proper design" led to "sharper edge on the spline (No. 1 to No. 2). The idea of "knobs without the metallizing" came from "roughen up the surface" (No. 4

from No. 3). "Colored plastic tape" probably came from "paper tape" (No. 6 from No. 5). "Ferrule" probably led to "roughen up the surface with a hot tool" (No. 8 from No. 7). The combination of "heat swedging" on a ferrule, combined with "another piece of plastic" probably led to "a special piece of plastic made up which slipped over the end" (No. 11 and No. 12 led to No. 13).

Question 4

Q. What role did Gary play in the finding of the solution that was adopted?

A. Gary did not solve the problem. However, after John took time to explain the problem to Gary, he got back on the previous train of thought inherent in solutions 5 and 6 (tape on the knob). He then came up with No. 14 (plastic cap). Gary gave new information that made it possible to select it as the plan to follow.

Question 5

Q. What assumptions were made by the problem solvers, implicitly or explicitly, which limited their action?

A. They appeared to assume that the Styling Manager's approval would be difficult to get and rejected many possible solutions on his behalf. Some students have wondered why the Styling Manager was not brought in to help solve the problem. Other assumptions mentioned by students were the time and cost limits, but these apparently were not as serious as the reluctance to consult with an expert such as the Styling Manager.

About two hours are required to read the case and discuss the above questions in small groups, including a twenty-minute plenary discussion of the results.

Additional Questions

A lively discussion of this case can be had if opposing groups of five to ten persons argue that "John is the best problem solver" (Bob for the other side). Since Bob and John have both good and bad points, the groups go deeply and intensely into the behavioral aspects of problem-solving.

This case may also be used to develop understanding of the social system in the industrial environment by questions like:

1. When Bob hears of the problem, he says "the fat's in the fire now. . . ." Why do you suppose this simple problem would cause so much consternation in Bob's company?

2. Later, John says, "Somebody's head will roll." He then seeks to pin the blame on a vendor. Why do you suppose he does this? What effect is it likely to have on his problem-solving ability?

Part D: Theory–Problem Solving And Designing

The use of this part is an instructor's option and will depend on the use to be made of the case studies.

The specific teaching objective of this part is:

–that the students learn a four-step problem-solving method. Its relation to designing is something the instructor may wish to emphasize or de-emphasize. A discussion of the open-ended questions follows:

Question 1

Q. What differences do you think there are between technical problem-solving and designing?

A. The differences between problem-solving and designing are small at a higher level of abstraction. At the detailed level of designing, more effort is put on the Need Analysis and Definition of the Design Problem than is put on a problem-solving diagnosis. This is because a problem is usually quite evident, whereas a user's needs are vague. Also, in designing, much effort goes into feasibility analysis and optimization of design solutions, whereas in most problems, the fit of the solution is apparent. For this reason the problem-solving is usually over when a solution is found, whereas in designing there is much communication, implementing and redesigning yet to be done.

Question 2

Q. What similarities?

A. It can be argued that designing and problem-solving are the same. It would be more correct to say that they follow the same pattern at the next level of abstraction.

Question 3

Q. Where would you find relevant information for finding alternatives for a problem with a neoprene seal between the drill and casing of an oil well drilling rig?

A. This can be discussed in relation to Step 2. One could use past experience. If the problem solver has none, he can inquire as to what has been done previously about the problem. One could consult others. He may ask his associates, a consulting engineer, other designers of oil rigs, vendors of neoprene, review patent records, consult other users of the seal, etc.

Question 4

Q. In general, what are some sources of alternative solutions?

A. In general, the sources of alternative solutions are set out in Step 2. However, this can be expanded to include textbooks, journals, competition, similar products, etc.

Question 5

Q. Think of one professional problem solver whom you know well, such as an engineer, doctor, dentist, lawyer, professor, etc. Was he or she problem or solution oriented in a case you remember? Why?

A. This is an exercise in understanding the text. A doctor who is solution-oriented is quick with a prescription after a fast look at the symptoms. One who is problem-oriented seeks tests and data to verify his diagnosis first.

Question 6

Q. Is the Problem-Solving Method shown here appropriate for a student to solve a non-technical personal problem?

A. The four-step method applies also to personal problems. This is a medium for students to practice the method in the absence of the regular flow of open-ended technical problems that the practicing engineer gets. A convenient work sheet is included in the Instructor's Guide.